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(56) Documents cited
GB 0633983 GB 0181744
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GB 0385909 US 4466244

(58) Field of search
F1S
Selected US specifications from IPC sub-class F03B

(54) Generating power from changes in liquid levels

(57) The pumping effect of a rising and falling liquid surface eg tidal, wave or lock water, in a chamber 15 compresses a gas (eg air) and generates a vacuum which is stored in respective reservoirs 16, 17 for the subsequent performance of useful work eg raising water to drive an hydraulic turbine.

Various arrangements for the chamber 15 are described (Figures 1, 5, 6 7 and 8) as are tanks through which water is raised (Figures 2, 3 and 5 using either or both the power sources 16, 17 and associated valves, which are detailed. Also disclosed are arrangements for delivering water to power turbines (Figures 10 and 11), for heating water using an electric immersion heater (Figure 9) and a compressed gas engine powered from a solar heated gas container which is cooled by coolant pumped by the engine to enhance its recharging with gas.

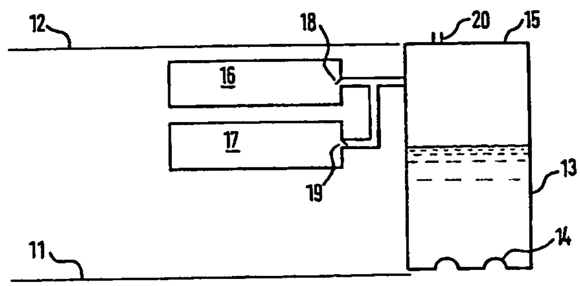

FIG.1.

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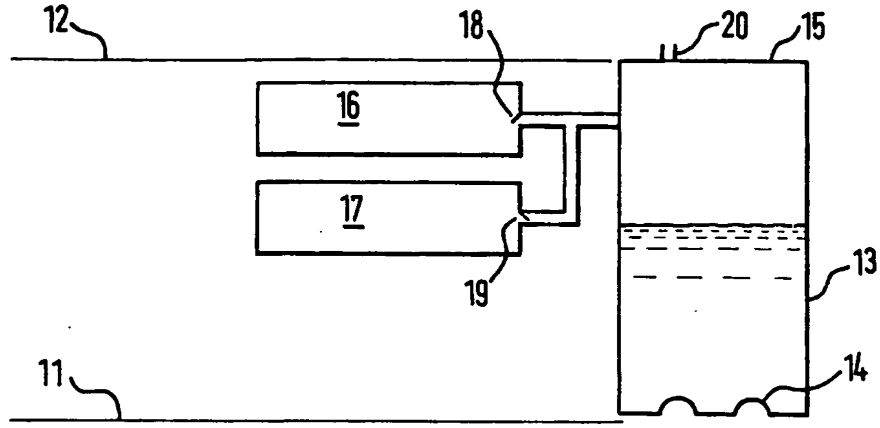
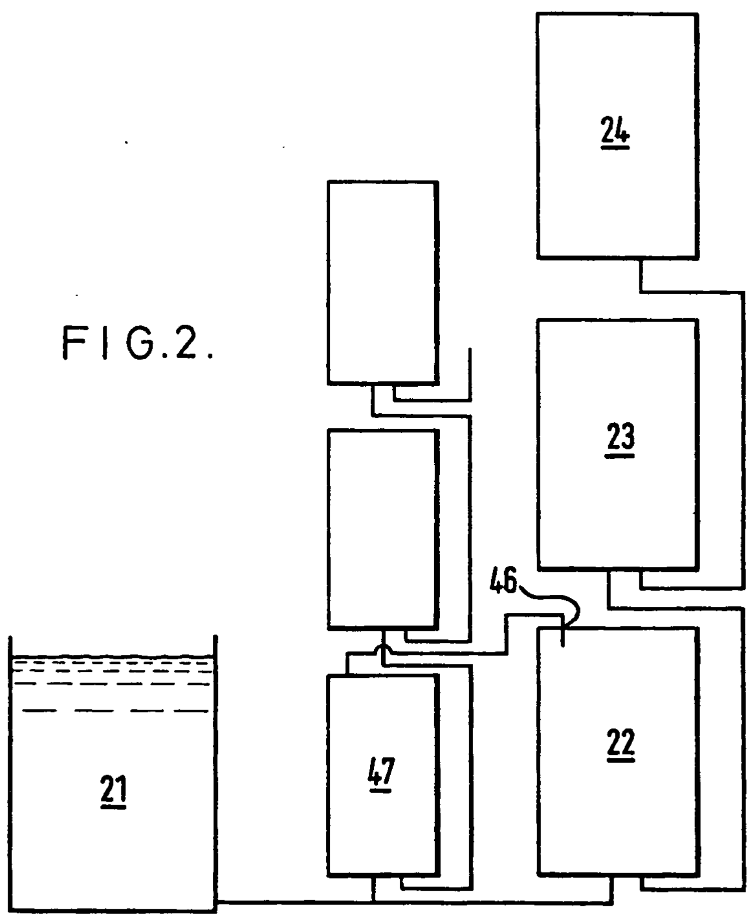
The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.



F I G. 1.

F I G. 2.



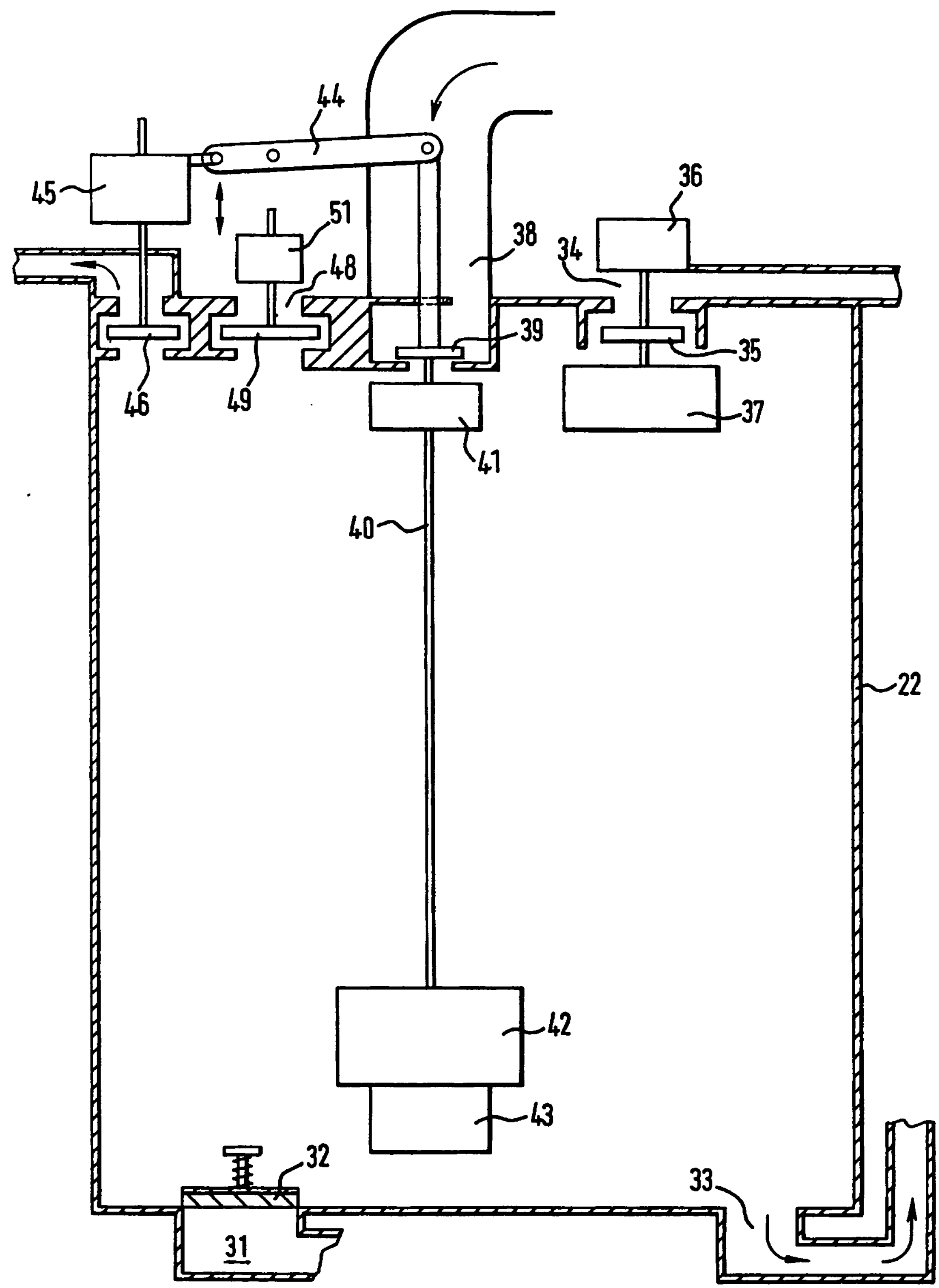


FIG.3.

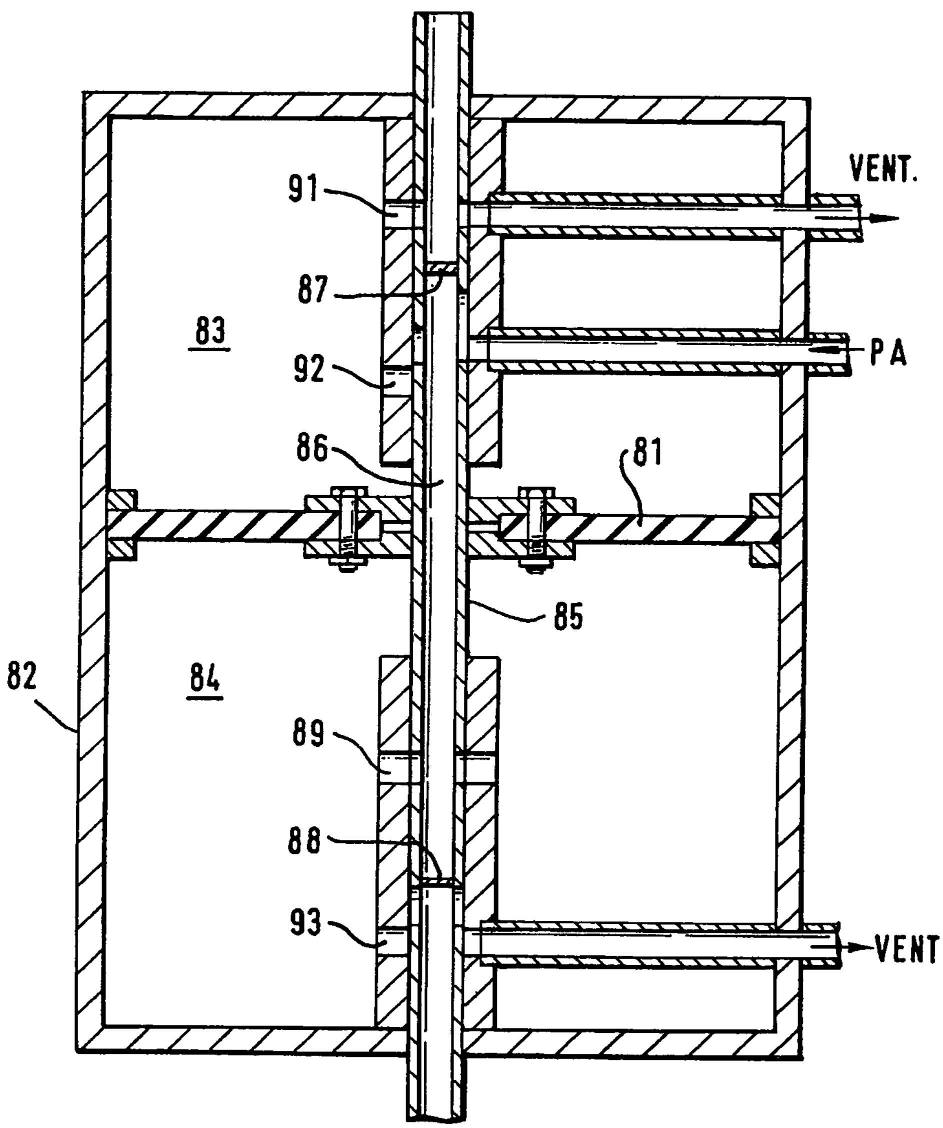


FIG. 4.

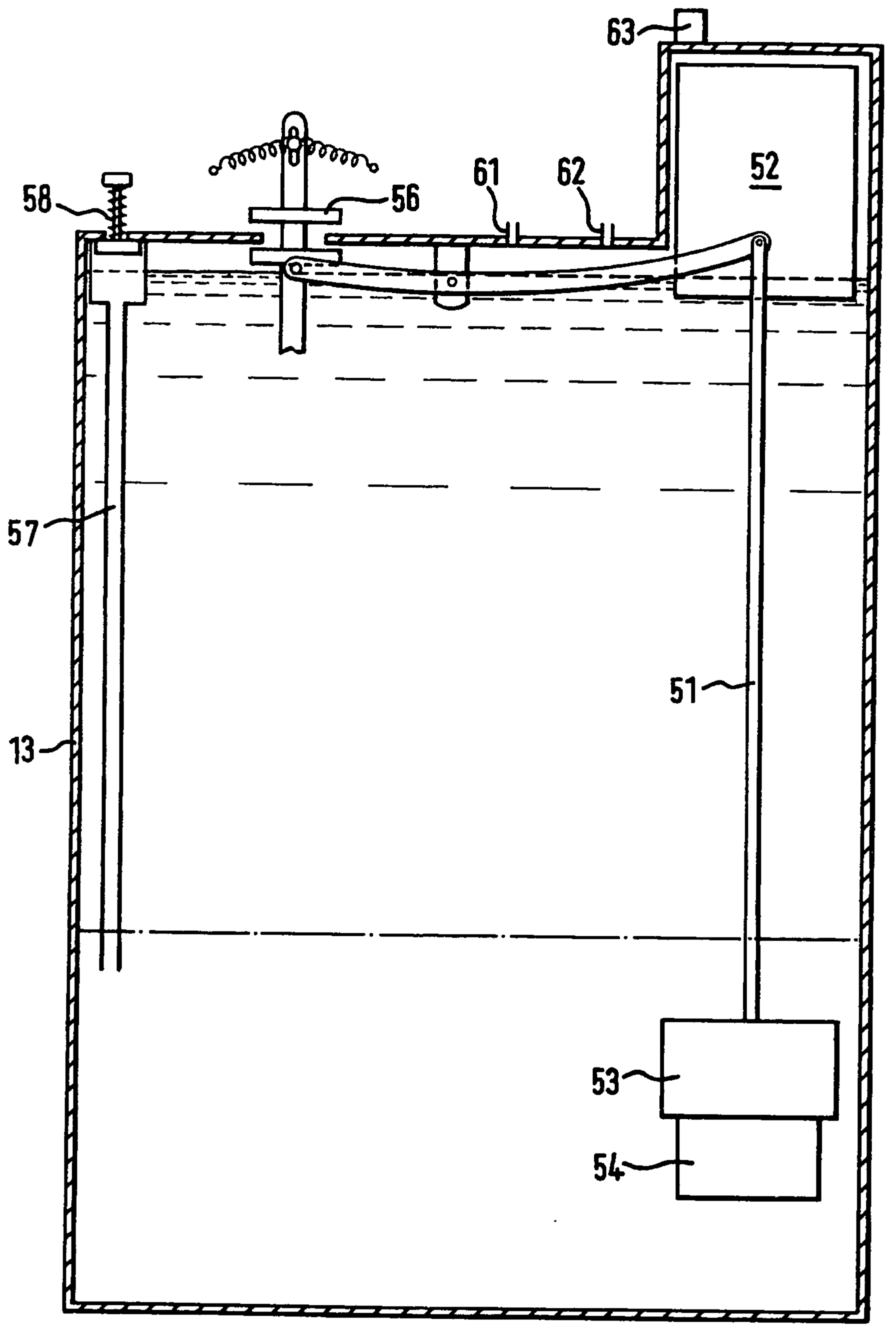


FIG.5.

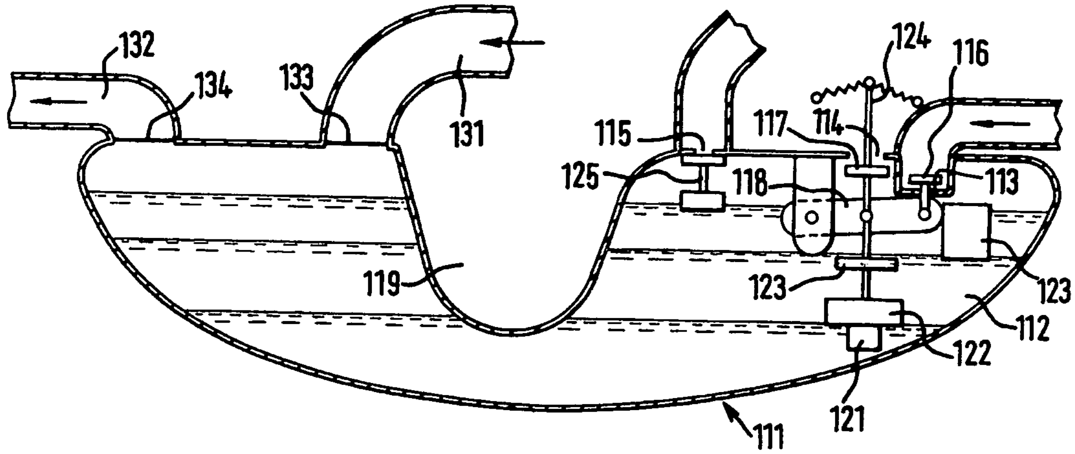

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FIG.6.

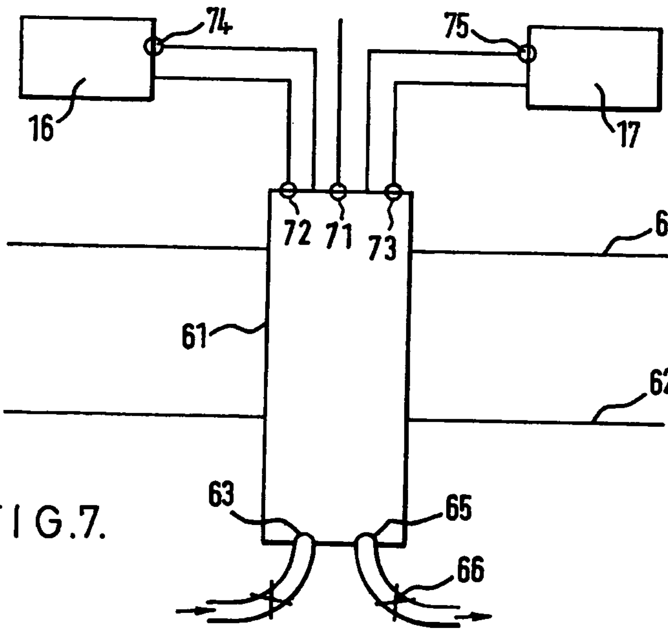
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FIG.7.

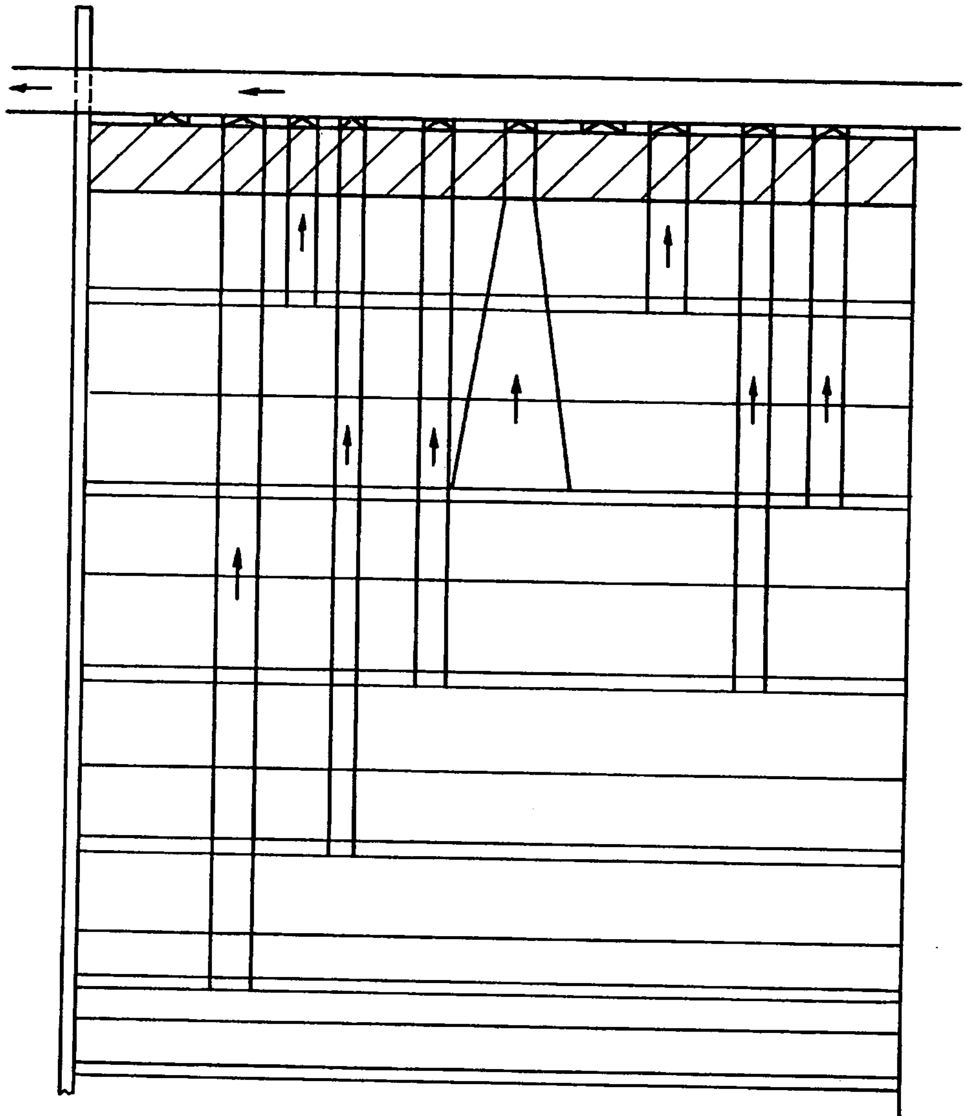

FIG.8.

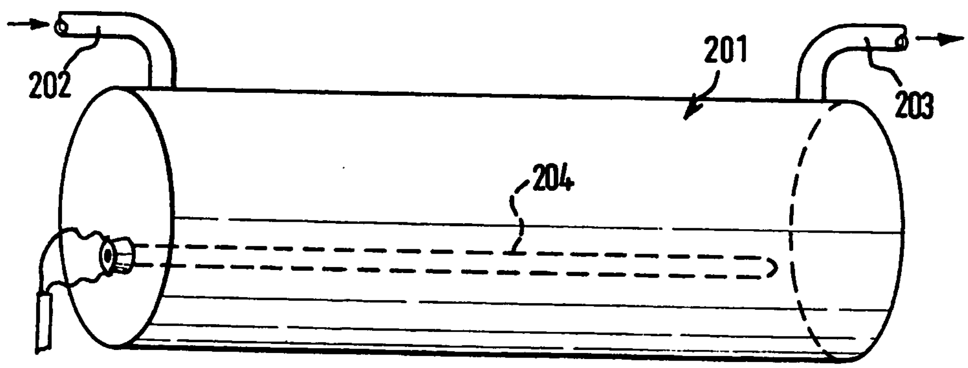

FIG.9.

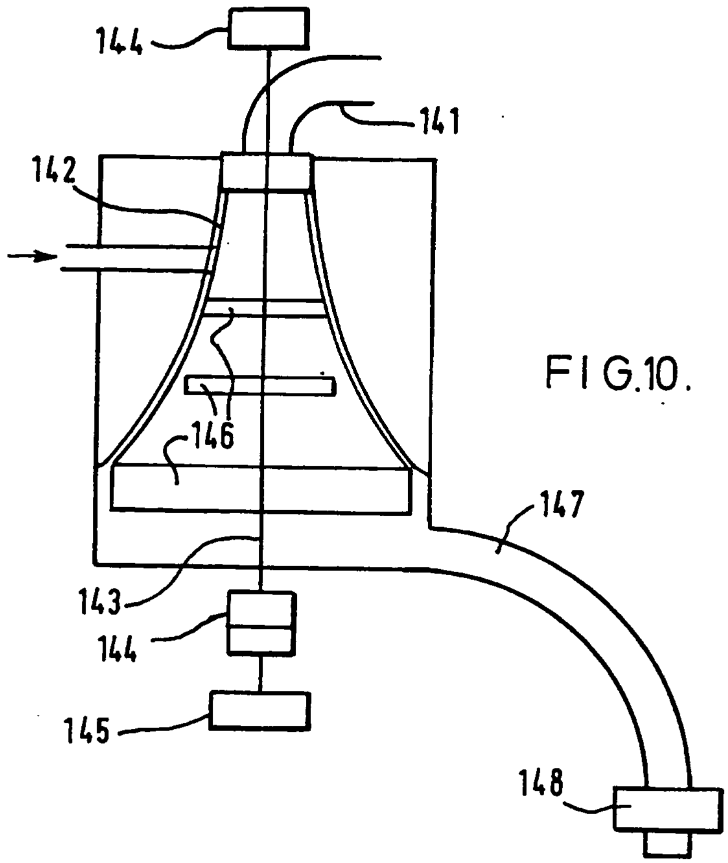
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FIG.10.

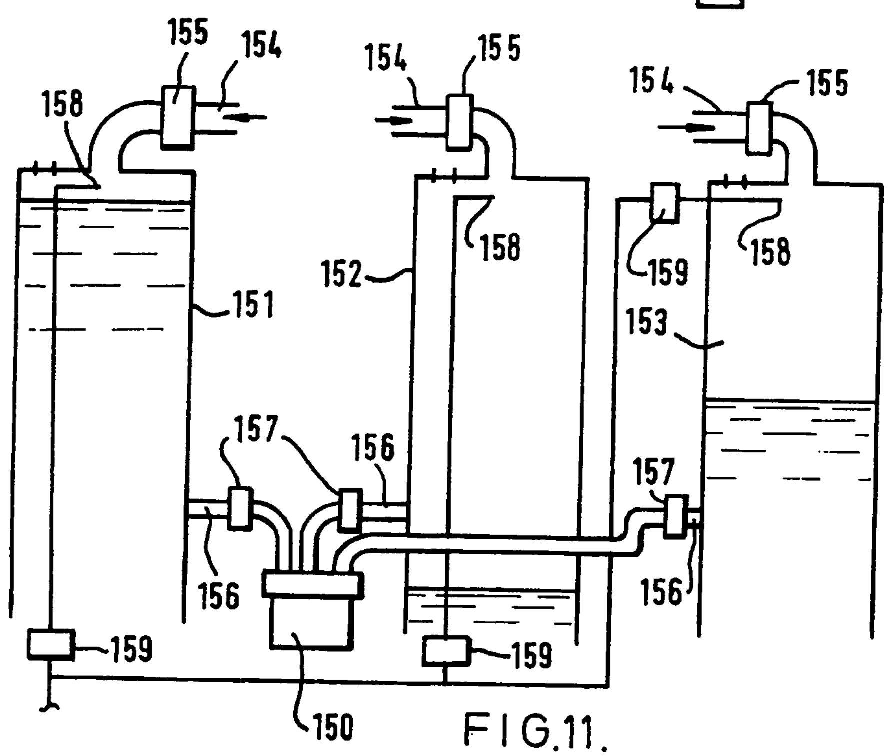
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FIG.11.

SPECIFICATION

Generating power from changes in liquid levels

This invention relates to generating power from changes in liquid levels, such as the tides. It has previously been proposed to allow water into a reservoir at or near high tide and to allow water from the reservoir to flow through a turbine back to the sea at or near low tide, the turbine being used to generate power, for example in the form of electricity, from the flow of water therethrough. Such apparatus requires a large reservoir to store the water from high tide and it is only possible to operate the turbine during periods around low tide if the exhaust port of the turbine connects with the sea.

It has also been proposed to provide a column with water of varying level entering at the bottom with the upper portion open to the air. The water in the lower portion is at a level equal or responsive to the instantaneous tide level and air moved into and out of the upper portion of the column is caused to operate an air turbine to generate power. Although the turbine can be operated almost continuously (except at the slack of the tides), the pressure differential across the turbine is so small that little useful power can be obtained.

The present invention uses a column as described above, but closes its upper portion and connects it to a reservoir through a non-return valve, so that the potential energy of the air under a pressure other than atmospheric caused by the change in level of liquid in the column can be stored for use as desired. The air under pressure can be accumulated until it reaches a desired pressure or volume at which a turbine or other device can be operated efficiently. Positive and negative pressure changes can be separately stored, accumulated during the flow and ebb tides respectively. The changes in liquid level do not have to be tidal; they could for example be the surges of waves in the sea, or changes of water level in a canal lock.

According to another aspect of the invention there is provided a toggle device operated bya pressure differential, the device comprising two chambers, a diaphragm separating the two chambers, an operating member connected to said diaphragm and valve means operated by movements of said member in two opposite direction and connectable between two sources of different pressure to apply said pressures to said chambers in two corresponding opposite senses so that a pressure differential exits across said diaphragm urging said member in the same direction as said movements. When the operating member moves in a first direction, it operates the valve means to so that the differential pressure across the diaphragm opposes movement of the member in the opposite direction. When a sufficiently large force is applied to the operating member the pressure differential on the diaphragm be overcome to move the valve means into the position in which the pressures applied to the two sides of the diaphragm are reversed and the force on the diaphragm will then oppose movement in the first direction.

According to a further aspect of the invention, there is provided a water heater for heating water flowing between an inlet and an outlet, the apparatus comprising a chamber located below the inlet and the outlet, and a water heater located within the chamber. The water heater is preferably electrically energised. This arrangement has the advantage that the heater is located at a low point within the water circuit, because it is below both the inlet and the outlet, and cannot therefore become accidentally exposed to air and thus burn out, at least until all the water has been boiled off. This heater may be used in any of the water pumping systems described in this or the earlier application.

Examples of the invention will now be described with reference to the accompanying drawings, in which:

Figure 1 is a diagrammatic representation of water raising apparatus taking power from the tides,

Figure 2 shows columns of tanks for use with the apparatus of Figure 1,

Figure 3 is a detail of Figure 2,

Figure 4 shows an alternative detail of the apparatus of Figure 1,

Figure 5 is a modification of Figure 1,

Figure 6 shows a tank for use with the apparatus of Figures 1 or 5,

Figure 7 is a schematic diagram of an alternative apparatus,

Figure 8 is a schematic diagram of apparatus for use with surging water levels, and

Figures 9 to *11* show apparatus for use with any of the previous Figures.

In the apparatus of Figure 1, the low tide level is indicated at 11 and the maximum high tide level indicated at 12. Between these two levels is a hollow column 13 having an inlet 14 for sea water and air just above low tide level 11 and having a closed upper end 15. This end 15 is shown at the level 12 but is not necessarily so. The air in the upper portion of the column 13 can be connected selectively to a pressure reservoir 16 and a vacuum reservoir 17 through non-return valves 18 and 19. AS the water level in the column rises, air is compressed and is forced into the reservoir 16; at high tide the column is vented to atmosphere at 20 and then closed again and as the water level drops air is drawn out of the reservoir 17. The reservoirs 16 and 17 are used to perform useful work in various ways.

One way is to raise water up a column of tanks, one above the other, as illustrated in Figure 2. Water is collected at near high tide level in a reservoir 21 and is fed from there to the bottom tank 22 in the column, shown in greater detail in Figure 3. At the bottom of the tank is a water inlet 31 closed by a non return valve 32 and a water outlet 33. The outlet 33 is connected to the inlet 31 of the tank above whose valve 32 prevents water flowing back to the tank below.

At the top of the tank 23 there is a vacuum connection 34 controlled by a valve 35 mounted on the armature of a solenoid 36 together with a float

37. The vacuum connection 34 supplies reduced pressure from the vacuum reservoir 17 of Figure 1.

A connection 38 supplying pressurised air from reservoir 16 is controlled by a valve 39 mounted on a linkage 40, a portion of which extends into the tank 22 and is connected to an upper float 41, a lower flat 42 and a weight 43. A spring toggle (not shown) controls the movement of the linkage 40, so that, as water falls in the tank 22 when the valve 39 is open, the weight 43 opposed by the buoyancy of float 42 will be insufficient to pull the linkage downwards to close the valve 39. When the flat 42 is uncovered, the weight 43 changes the state of the toggle and the valve 39 closes. The linkage 40 extends upwardly from the tank 22 and is connected through a lever 44 to a solenoid 45 operating a valve 46 in connection to a tank 47 of a secondary column (see figure 2). A vent 48 is provided controlled by a valve 49 operated by a solenoid 51. The tanks of the secondary column are smaller and more closely spaced since the pressure and vacuum applied to the tanks in this column are reduced from the values applied to the primary column after performing work in the primary column.

The operation of the column of tanks will now be described. When the tank 22 contains air under atmospheric pressure, the weight of float 37 will open the valve 35, connecting the tank to the vacuum reservoir 17. The pressure in the tank 22 is thus reduced and water is drawn through the inlet 31 and the valve 32 into the tank from the water reservoir 21. Even when the water has covered float 42, its buoyancy is insufficient to lift the linkage 40 against the resistance of the spring toggle and the weight 43. As the water rises towards the top of the tank 22, the float 37 closes the valve 35, thus disconnecting the vacuum supply. A switch (not shown) is closed by the closure of the valve 35 to activate the vent solenoid 51 to vent the tank and then to trigger solenoid 45 which moves the linkage 40 by means of lever 44 to open the valve 39 and allow air under pressure from the reservoir 16 into the tank 23 above the water, thus forcing water out of the outlet 33 into the tank above. When the water uncovers the float 42, the weight 43 is sufficient to change the state of the spring toggle and closes the valve 39. Valve 35 is maintained closed by solenoid 36 remaining energised. The air above the water in the tank 22 will still be above atmospheric pressure, and the movement of the lever 44 causes the secondary valve 46 to open, communicating the air under pressure to the secondary tank 47 indicated in Figure 2. The solenoid 45 closes the valve 46 after a period and triggers the solenoid 51 to open the valve 49 for a further short period to return the pressure within the tank 22 to atmospheric pressure, after which the solenoid 36 is triggered to open the valve 35 and the cycle repeats itself. The operation of the secondary column including the tank 47 :opand any further columns if provided) is similar to that of the primary column and is not separately described.

It will be noted that the valves 46 and 49 have seats above and below the valve member. This allows the valve to close on upward movement of the valve member when the pressure inside the tank 23 is above atmospheric pressure and on downward movement when the pressure is below atmospheric pressure, no great force being required to keep the valve closed.

Instead of using a switch closed by closure of the valve 35 to operate the vent solenoid 51 and trigger the solenoid 45, a float 41 can be used to lift the linkage 40 as described above, operating the solenoids 51 and 45 at the appropriate times. The float 41 is positioned above the float 37 so that the valve 35 closes before the valves 46 and 49 open. As the water level drops, uncovering of the float 41 does not cause the linkage 40 to move since the weight 43 is still opposed by the buoyancy of float 42.

It is possible to operate the column of tanks solely with the vacuum supply or solely with the pressurised air supply, since water can be raised by applying vacuum from above or pressure from below, or both.

The spring toggle for controlling the movement of linkage 40 ensures that when the linkage has been moved to one end of its path of movement, it requires a substantial force to return it back along the path to its other end. Thus, when the weight 43 has pulled the linkage 40 down as the water level in tank 23 falls, the spring toggle will prevent the linkage rising again when the water level again rises to cover the float 42. Only when the water has covered the float 41 as well and/or an additional force to lift the linkage has been applied by the solenoid 45 will the resistance of the spring by overcome and the linkage will rise in response to the buoyancy of the floats 41 and 42 and any force applied by the solenoid 45.

As an alternative to the spring toggle arrangement described above, the arrangement illustrated in Figure 4 may be used. A rubber diaphragm 81 is sealed across the mid-portion of a container 82, dividing the container 82 into a first chamber 83 and a second chamber 84. A hollow operating member 85 is connected to the diaphragm 81 and can be moved axially of the container 82. A source of air under pressure PA (conveniently from reservoir 16) is permanently connected to the central portion 86 of the bore of the member 85 defined by stops 87 and 88 through an elongated aperture 88 in the operating member 85. When the member 85 is in its upper position the central portion 86 is connected through an aperture 89 to the lower chamber 84, while the chamber 83 is connected through aperture 91 in the member above the stop 87 to atmospheric pressure, so that the differential pressure across the diaphragm urges the member 85 upwards, resisting any small downward forces. When a sufficiently large downward force is applied to the member 85, the upward force from the diaphragm is overcome and the member moves to its lower position in which the air under pressure is disconnected from the lower chamber 84 by closure of the aperture 89 and connected to the upper chamber through aperture 92. The apertures are

arranged so that one aperture is closed before another is opened so that there is no cross connection between the source PA and atmospheric pressure. At the same time the aperture 91 is closed and aperture 93 below the stop 88 opens to connect the lower chamber 83 to atmospheric pressure. The differential pressure across the diaphragm now reinforces the downwards movement, resisting any small upward forces on the member 85.

The use of a pneumatic toggle system rather than a spring has advantages in an environment which may damage the resilient properties of a normal spring.

Figure 5 illustrates a modification to the air column 13 of Figure 1. In this modification, the linkage 51 connects an upper float 52 to a lower float 53 attached to a weight 54 and by means of a lever 55 operates a double valve 56 in the upper wall 15 of the air column 13. A pipe 57 extends from the upper wall 15 to almost the bottom of the column 13 and is connected to the atmosphere at its top end by means of a non-return valve 58 to release vacuum within the column 13. Connections 61 and 62 are indicated diagrammatically to the air reservoir 16 and vacuum reservoir 17 respectively, and a non return valve 63 connects the top of the chamber for the float 52 to the atmosphere.

When the column 13 is full of air, the weight 54 keeps the lower part of the valve 56 in contact with the upper wall 15 of the column, thus preventing escape of air from the top of the column. The buoyancy of the flat 53 balances the weight 54, so that there is no net upward force when these components are immersed to move the valve 56, and the excess pressure above the water is available to be connected through 61 to the pressure reservoir 16. When the water reaches the top of the column 13, the float 52 is partly immersed, causing the valve 56 to be opened to return the air above the water level to atmospheric pressure. The valve 56 has a toggle arrangement which allows the valve 56 to vent the top of the chamber as the valve moves from sealing the top of the chamber against excess air pressure to sealing the top of the chamber against below-atmospheric air pressure as the upper seal of the valve 56 engages the top wall 15. After the tide has turned, the water level within the column 13 will drop and the air above the water will decrease in pressure and this lower pressure is transmitted to the vacuum chamber 17 through connection 62. Although the flat 52 is no longer immersed as the water level drops, the weight 54 balances the buoyancy of the flat 53 so that the valve 56 is not changed in state until the water level drops below the float 53. At this stage, the connection 62 to the vacuum chamber is closed and the weight 54, no longer balanced by the buoyancy of the float 53, will cause the valve 56 to return to its initial state and the interior of the column is vented to atmosphere through the pipe 57 after the water level has dropped below the end of the pipe 57.

In order to allow unrestricted access to the inlets 14, the shore would have to be excavated to a suitable depth. The excavated area could also serve as a lake for recreation or could be covered over and built upon. The reservoir 21 and the access to the inlets 14 could be combined in a creek consisting of an outer high tide level basin with a central basin communicating with the instantaneous sea level by dividing the space or in two basins formed between two walls of a causeway across the sea. The high tide basin would have lock gates for sea traffic to enter and leave that basin. This arrangement would facilitate electricity generation, as well as to move freely at all tidal states.

In order to increase the kinetic energy of water at a turbine used to generate electricity from the water flow, the cross section of the water inlet can be decreased at the entry to the turbine.

In the arrangements so far described mechanical pumps are not required, so that the inefficiency in prior art arrangements using the flow of water between different tidal levels to drive a turbine which itself drives a pump is avoided. The water raised to an upper tank may itself be useful, or its increased potential energy can be used for example to generate electricity. The air from the pressure reservoir 16 may be used to increase the kinetic energy of water flowing from a high level reservoir to a turbine generator, for example by the apparatus as illustrated in Figure 10. Water in a conduit 141 enters the apex of the inner chamber of a hollow conical rotor 142 which is rotated about an axial shaft 143 mounted on bearings 144 by a motor 145 driven by air from the reservoir 16. The rotor 142 has diametral strengthening ties 146 which also serve to drag the water round with the rotor so that at the bottom of the rotor the water is flung out by centrifugal action along an outlet conduit 147 to the turbine generator 148 with greater kinetic energy than it would have had by simply falling through the height of the rotor 142. Friction between the rotor and the side walls of the enclosing chamber 148 is reduced by applying air from the reservoir 16 thereto at 149 to form an air cushion.

Another arrangement by which the kinetic energy of water entering the turbine 150 of a generator can be increased is shown in Figure 11. Three columns 151, 152 and 153 are provided, each with an inlet 154 for water with a control valve 155, an outlet 156 for water to pass to the generator turbine with a control valve 157 and an inlet 158 at the top for air under pressure with a control valve 159. When the first column 151 has been filled by opening the water inlet control valve 155, that valve is closed and the other two valves 157 and 159 are opened so that air presses down on the top of the water to force it out of the column 151 to the turbine 150 with increased kinetic energy, the valves 157 and 159 being closed again when the column is empty. Meanwhile the inlet control valve 155 of the next column 152 has been opened to fill that column, and the process continues. Although this system could be operated with two columns acting in antiphase, it is more convenient to have at least three columns in order to allow an overlap between one column and another in the

filling of the columns and the supply of water to the turbine. Non-return valves can be supplied as necessary to prevent any reverse flows of water due to differential pressures in the columns connected to the water supply 154 or generator turbine 150.

Although in normal circumstances the columns 13,18 are of strong materials such as reinforced concrete, a portable version of the apparatus could be provided with columns of lightweight flexible material such as rubberised canvas. The column or columns would be anchored to the sea bed with wieghts, such as sand bags, possibly fitting in pockets in the canvas. Columns for collecting air under pressure would be self supporting, but columns for collecting air at reduced pressure would require some internal support structure. The column can be made of light-weight flexible material formed into a double-walled column, the double wall structure providing air passages. When water enters the column, it tends to compress the volume between the double walls of the base, thus forcing air into the double walls forming the upright walls of the column, tending to make them more rigid, thus defining the remainder of the column for the water to fill as the level rises.

The columns so far described need not be cylindrical. A tapered column in which the cross section reduces towards the top may be used to amplify the compression effect of the surging waves. A diagrammatic illustration of such columns with one shown as conical is included as Figure 8. The columns illustrated in Figure 8 collect by means of non-return valves into a pressure pipe at their upper ends, and there lower ends are at a number of different levels. The levels are chosen to suit the various tide levels. When the water feeding the pipes in non-tidal but has waves, then the lower ends of the pipes can be spread over a much smaller range of levels.

Figure 7 shows another application of the pressure column described above. In its basic form, this column 61 extends below low tide level 62 with a water inlet 63 at its base. In the immediately following description, this inlet 63 is not valved, but according to a modification it is valved, and an outlet 65 with a control valve 66 to a turbine is also provided at the bottom of the column and also provided with a valve. The top of the column 61 is shown at high tide level 64, but need not be at that level. The top of the column 61 is normally sealed, but can be vented by opening a valve 71. It can also be connected throught a non-return valve 72 to a pressure reservoir 16 and through a non-return valve 73 to a vacuum reservoir 17. It is possible for one of the reservoirs 16, 17 to be omitted, if desired. The reservoirs 16 and 17 are also connected through respective valves 74 and 75 to the interior of the column 61.

The operation of the apparatus of Figure 7 is best considered starting with the interior of column 61 and the reservoirs 16 and 17 at atmospheric pressure and the water at low tide level 62. As the tide rises, water enters the column through inlet 63 and compresses the air within the column 61, the compressed air passing through valve 72 to increase the pressure in reservoir 16. When the water reaches high tide level, air under maximum pressure has passed into the reservoir 16 and the column 61 is momentarily vented to atmospheric pressure through valve 71. As the tide drops again, the pressure within column 61 will decrease and air will be drawn through the valve 73 from the reservoir 17, reducing the pressure therein. At low tide, the pressure is again returned to atmospheric by momentarily venting though valve 71, and then valve 74 is opened to compress the air within column 61 to a value above atmospheric pressure, by means of the increased pressure air stored within reservoir 16, so that the water level within column 61 will fall below level 62. Valve 74 is closed again, and as the tide rises the air within column 61 will be compressed again and the pressure will rise to a greater value than that during the first cycle since the initial pressure of the second cycle is higher than that of the first cycle. As before, air enters the reservoir 16 through valve 72. At high tide, the pressure in column 61 is returned to atmospheric by momentarily opening valve 71, and then reduced to below atmospheric by opening valve 75, thus drawing the water level above level 64. Valve 75 is then closed again and as the tide drops, the pressure within column 61 is further reduced by the falling tide, thus extracting more air from the reservoir 17. Again, the final pressure within column 61 at the second cycle will be lower than the final pressure of the first cycle since the initial pressure is lower in the second cycle than in the first cycle. The process then repeats with the pressures in the reservoirs moving further from atmospheric with each cycle.

If one of the reservoirs 16 and 17 is omitted, the column can remain vented to atmosphere through valve 71 during the whole of the first or the second half of each cycle depending on whether it is the reservoir 16 or 17 which is omitted.

When the vacuum reservoir 17 is omitted, and the inlet 63 valved and an outlet 65 to a turbine is provided, the column operated in the manner described above during the rising tide, up to the venting of the column to atmospheric pressure through valve 71. After the venting of the column through valve 71, valves 74 and 66 are opened so that water is forced by the excess pressure in reservoir 16 through the outlet 65 to the turbine to perform useful work. If the pressure in resrevoir 16 should fall to atmospheric, the column would again be vented through valve 71.

When it is desired to drive the water in the columns 61 to the turbine through outlet 65 with a pressure which is higher than that which can be achieved in the resevoir 16 after a single rise of the tide in the column 61, the pressure in the resevoir 16 can be built up by several cycles of operation as described above in the initial description with reference to Figure 7, the valve 66 being opened with the valve 74 when the water in the column 61 has reached its maximum level and the pressure in the reservoir 16 has reached the desired value.

The drive to the turbine through the outlet 65

with the arrangement described is intermittent. When a more uniform drive is required, a plurality of columns 61 may be provided, operating at different phases so as to smooth out the drive to the turbines. Similarly, the very high pressure available in the reservoir 16 from several cycles of operation of the column 61 is only available after each plurality of cycles, and so it is again only intermittently available. It would be possible to provide a number of different resevoirs 16 connected to the or each column 61, the build up of pressure being started at different times for each reservoir, so that they reach their maximum pressure level at different times and between them can provide a more frequent drive to the turbines by exerting excess pressure on the top of the water surface in the column 61.

As has been described with reference to earlier figures, the valves of column 61 can be operated by floats within the column, so that they operate when the water in the column reaches predetermined levels. The toggle arrangement already described can be used when it desired that a valve should open, for example, when the water level rises past a certain level but should not close again when it drops through that same level, but only when it drops to a different level.

Another application of the basic column described above is illustrated with respect to Figure 6. A chamber 111 has a main working portion 112 in the top of which is a driving gas entry port 113 from the pressure reservoir 16, a vent port 114 and an optional vacuum port 115 which is connected to the reservoir 17. Valves 116 and 117 control the opening of ports 113 and 114 and are moved together on a lever 118 from one position in which the valve 116 opens the port 113 and and the valve 117 closes the port 114 to a second position in which valve 116 closes port 113 and valve 117 opens port 114.

A weight 121 attached to a float 122 is secured to a lever 118 to lie near the bottom of the chamber portion 112 so that the float 122 is just exposed when the liquid in the chamber 111 reaches its minimum level. A float 123 is attached to lever 118 at a higher level than the float 122. A spring toggle 124 maintains the lever 118 and the valves in its position until either both float 122 and 123 are exposed or until they are both submerged by the liquid in the chamber 111.

Assuming the water level in the chamber portion 112 is at a maximum, with both floats 122 and 123 submerged, lever 118 will be lifted so that valve 116 opens port 113 and valve 117 has closed port 114 so that the interior of the chamber portion 112 is sealed from the atmosphere. Driving gas under pressure enters the chamber through the port 113 and drives the water level down within the portion 112 and correspondingly up within the other portion 119 of the chamber which is U-shaped. As the water level drops in the chamber portion 112, the float 123 becomes exposed, but the spring toggle 124 maintains the lever 118 lifted to maintain the valve 116 open and the valve 117 closed. As the water level drops further under the influence of air under pressure from the port 113, the float 122 becomes exposed whereupon the weight 121 overcomes the lifting force of the spring toggle 124 and causes the lever 118 to drop, thus closing the valve 116 and opening the valve 117. The air under pressure over the water level thus escapes from the vent 114 and the water level returns to its original height and the water level correspondingly drops in the other portion 119 of the chamber 111. As the float 122 is again submerged, its buoyancy is insufficient to overcome the resistance of the spring toggle 124 so that the valves 116 and 117 remain in their new positions. However, when the float 123 becomes submerged, the combined buoyancy of the floats 122 and 123 overcomes the resistance of the spring toggle 124 and lifts the lever 118 again, thus closing the vent 114 and reconnecting the air pressure to the chamber portion 112 through the port 113. The cycle then repeats.

With this arrangement, in one half of the cycle air under pressure at the port 113, but the other half of the cycle is a relaxation portion. The second half of the cycle can also be made to be a driven portion by including the vacuum port 115 and a corresponding valve 125 to control the opening of the port 115. With this arrangement, the valve 117 is modified so that when the lever 118 drops, valve 117 only momentarily opens the port 114 in order to return the interior of the chamber portion 112 to atmospheric pressure and then closes again, and thereafter the valve 125 opens so that the interior of the chamber portion 112 is evacuated and the water within the chamber portion 112 is drawn upwards. Similarly, when the lever 118 rises, the valve 125 closes the port 115 and the valve 117 momentarily opens the port 114 to return the interior of the chamber portion 112 to atmospheric pressure and thereafter the valve 117 closes and the valve 116 opens to allow air under pressure into the chamber portion 112. Suitable linkages or time-delay mechanisms are available to operate the valves in this way and are not specifically described.

The portion 119 of the chamber 111 will thus have a water level which rises and falls. The rise and fall of the water surface is used to pump a gas supply from an input line 131 to an output line 132. Non-return valves are provided to prevent gas returning through the inlet line 131 from the chamber portion 119 and into the chamber portion 119 from the outlet 132. As the water level in the chamber portion 119 drops, gas will be drawn through the valve 133 from the inlet 131. As the water level rises, gas will be forced through the valve 134 into the outlet pipe 132.

The driving gas at port 113 is provided from the high pressure reservoir 16 described. An alternative source of driving gas under pressure can be arranged in hot climates by introducing driving gas into a sealed container and allowing the sealed container to be heated by the sun. The gas is thus pressurised and can be used to drive an engine (or the apparatus as described above). Besides doing useful external work, the engine may be used partly to pump cool ng liquid to the sealed con-

tainer to cool it before refilling with gas so that the maximum weight of gas can be accommodated, after which the cycle repeats.

Figure 9 illustrated a cylindrical water heater 201, with its axis horizontal, an inlet 202 at one end and an outlet 203 at the other, both inlet and outlet being at the top of the cylinder. An immersion heater 204 extends within the cylinder from one end parallel to but a little below the axis. The arrangement of inlet and outlet ensures that the heater 204 is always immersed by the water so that damage due to overheating is unlikely.

CLAIMS

1. A gas pump comprising a column which can be sealed at the top, means for introducing water into the column so that a variation in water level in the column when sealed will cause a variation of gas pressure within the column and means for controllably conducting gas from the column to perform useful work.

2. A pump as claimed in claim 1 wherein said conducting means is connected to a pressure reservoir through a first non return valve and to a vacuum reservoir through a second non return valve, so that when the gas pressure in the column exceeds that in the pressure reservoir, gas enters the pressure reservoir to increase the pressure therein and when the gas pressure in the column drops below that in the vacuum reservoir gas is drawn out of the vacuum reservoir to reduce the gas pressure therein.

3. A container comprising a pair of flexible walls, one defining an interior chamber and the two defining between them a compartment which can be sealed and which extends around all sides of the interior chamber.

4. A toggle device operated by a pressure differential, the device comprising two chambers, a diaphragm separating the two chambers, an operating member connected to said diaphragm and valve means operated by movements of said member in two opposite directions and connectable between two sources of different pressure to apply said pressures to said chambers in two corresponding opposite senses so that a pressure differential exists across said diaphragm urging said member in the same direction as said movements.

5. A water heater for heating water flowing between an inlet and an outlet, the apparatus comprising a chamber located below the inlet and the outlet, and a water heater located within the chamber.

6. An engine assembly comprising an engine operated by gas under pressure, a container for said gas, a pump driven by said engine and means to supply cooling fluid, said pump being connected to said means to supply cooling fluid to cool the container when gas inside has expanded on heating of the container and the gas pressure has been reduced aft driving said engine.

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